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(54) Title: INTERACTIVE DEFORMATION MAP CORRECTIONS

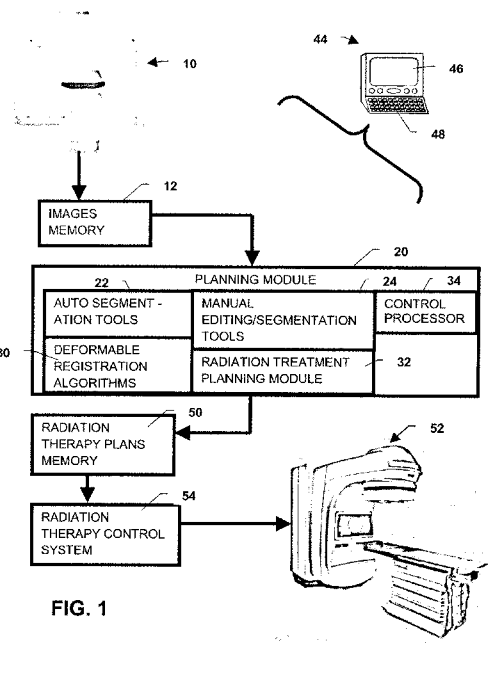

FIG. 1

(57) Abstract: A radiation therapy planning system includes a planning module (20) which receives a first planning image set from a diagnostic imaging apparatus (10) and uses automatic segmentation tools (22) or manual segmentation tools (24) and a radiation therapy planning system (32) to generate a first radiation therapy plan. After the first radiation therapy plan has been applied for one or more therapy sessions, a second planning image set is generated. The planning module (20) uses a deformable image registration algorithm (30) to register the planning image set sand generate a corresponding deformation map which is applied to segmented objects of interest (OOIs) of the segmented first planning image set to propagate the objects of interest onto the second planning image set. The deformation map is corrected in accordance with deviations between the propagated and actual OOI locations in two steps: 1) manual and/or automated corrections of the propagated OOIs are performed, such as region of interest contour corrections and/or landmark point of interest positions; 2) a corrected global deformation map is generated from these local OOI corrections. The corrected deformation map is applied to the first radiation therapy plan and an accumulated radiation map depicting the radiation accumulated in each OOI during the therapy session(s) implemented with the first radiation therapy plan.

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INTERACTIVE DEFORMATION MAP CORRECTIONS

DESCRIPTION

The following relates to the medical diagnostic imaging arts, radiation therapy arts, medical arts, radiation therapy planning arts, image processing arts, and related arts.

In various medical treatments, diagnostic images are taken from time to time to monitor progress of a treatment regimen, advancement of a medical condition, or plan a treatment course. For example, in radiation therapy, using information from diagnostic image as a guide, spatially targeted dosages of ionizing radiation are applied to a tumor or other region containing cancerous or malignant tissue. Growing and rapidly multiplying cancer cells tend to be more susceptible to damage from ionizing radiation as compared with normal cells, and so enforced by the higher dosage administrated by proper planning, the applied radiation preferentially kills cancerous or malignant tissue. Because ionizing radiation is harmful to both malignant and healthy cells, precise spatial targeting of the radiation is important for applying effective radiation therapy to the malignancy while limiting collateral damage to healthy tissue.

In radiation therapy, the radiation beam is applied at angular positions around the subject in a manner that combines to produce a targeted total radiation dosage spatial distribution that is concentrated on the tumor or other region to be treated, while keeping the integrated exposure of certain radiation-sensitive critical organs below a safety threshold. Angular coverage can be achieved by using a plurality of stationary radiation sources distributed around the subject, or by rotating a single radiation source such as a linear accelerator (LINAC) around the subject. The radiation therapy is planned in advance for a specific subject, based on imaging data acquired of that subject. Typically, computed tomography (CT) imaging is used for radiation therapy planning, although other imaging modalities such as magnetic resonance (MR), positron emission tomography (PET), single photon emission CT (SPECT), ultrasound, and the like may also be utilized to supplement the CT data.

To plan a radiation therapy course, the tumor or other target is identified and delineated in the images, along with delineation of radiation-sensitive "risk" organs or regions whose radiation dosage must be limited. Radiation plan parameters are provided by the oncologist or other medical personnel. The radiation therapy plan parameters typically include a minimum or target dose to be delivered to the malignant tumor, and maximum permissible dosages for the risk organs or regions. The contoured targets and organs at risk together with the radiation therapy plan parameters and known information about radiation attenuation or absorption characteristics of the various tissues serve as inputs to optimize the radiation beam spatial profile and intensities to concentrate the radiation in the target while limiting exposure of risk organs in a deformation map.

In radiation therapy planning and certain image studies, deformable image registration is becoming an important tool. Deformable image registration is mapping of individual volume elements from one image to another image using non-rigid translation and/or rotations. That is, each volume element of the image is mapped separately. Deformable image registration is required when anatomical differences exist between images that are beyond rigid translation/rotation. Some applications of deformable image registration include propagation of Object(s) of Interest (OOIs) such as contours or Region(s) of Interest (ROIs) and landmarks or Point(s) of Interest (POIs), deforming PET/CT studies to a CT acquired for treatment planning for contouring and evaluation, and/or accumulation of dose computed on multiple image sets of the same patient. Deformable image registration can be used for cases such as, but not limited to, adaptive planning for a patient during the course of therapy, 4-D planning/optimization, composite planning, and multimodality treatment plan generation.

In order to generate an accumulated dose, doses computed on multiple image sets are mapped or deformed to the same coordinate frame. The accuracy and precision of this mapping is important because errors in the mapping can result in errors being propagated when the mapping is applied to OOIs or accumulated doses. In almost every case, significant errors in the generated mapping are present as a result of limitations of the automated algorithms.

The following provides a new and improved apparatus and methods that overcome the above-referenced problems and others.

In accordance with one aspect, a radiation planning module is configured to update a first radiation therapy plan (RTP) generated with a first planning image set that has been segmented to define locations of Object(s) of Interest (OOIs), including contours delineating Region(s) of Interest (ROIs) and/or landmarks indicating Point(s) of Interest (POIs). The planning module receives a second planning image from an imaging device and registers the first and second planning images and generates a first transform deformation map which transforms one of the planning image sets into alignment with the other. The OOI locations are operated on with the deformation map to propagate the OOI locations onto the second planning image set. The deformation map is corrected in accordance with deviations between the propagated OOI locations and locations of the corresponding OOIs in the second planning image set. The first radiation therapy plan is replicated and the replication adjusted with the corrected deformation map to generate an updated radiation therapy plan for the second planning image set.

In accordance with another aspect, a method of updating a first radiation therapy plan generated from a first planning image set that has been segmented to define locations of Object(s) of Interest (OOIs), including contours delineating Region(s) of Interest (ROIs) and/or landmarks indicating Point(s) of Interest (POIs) is provided. A second planning image set is received and the first and second planning image sets are registered with a computer-implemented algorithm to generate a first deformation map which transforms one of the planning image sets into alignment with the other. The deformation map operates on the object of interest locations to propagate the object of interest locations onto the second planning image set. The deformation map is corrected in accordance with a deviation between the propagated OOIs and locations of the corresponding OOIs in the second planning image set. The first radiation therapy plan is replicated and the replication adjusted with the corrected deformation map to generate an updated radiation therapy plan for the second planning image set.

In accordance with another aspect, a radiation planning module is configured to contain a first planning image that has been segmented to define locations of Object(s) of Interest (OOIs), including contours delineating Region(s) of Interest (ROIs) and/or landmarks indicating Point(s) of Interest (POIs). The planning module receives an image pair where both images are in the same coordinate frame. The planning module registers the first planning image with one of the images from the image pair and generates a first transform deformation map that transforms the planning image set into alignment with the other images. The OOI locations are operated on with the deformation map to propagate the OOI locations onto the second planning image set. The deformation map is corrected in accordance with deviations between the propagated OOI locations and locations of the corresponding OOIs in the second planning image set. Both images in the image pair are operated on with the deformation map to generate deformed images such that all three images are in the same coordinate frame.

One advantage resides in providing a deformation map for a treatment plan with less deformation errors.

Another advantage resides in providing more accurate mapping for treatment dose planning and tracking.

Another advantage resides in providing a radiologist or other medical professional to generate an improved deformation map.

Another advantage resides in providing a radiologist or other medical professional to generate an improved deformed image for contouring and analysis.

Further advantages will be apparent to those of ordinary skill in the art upon reading and understand the following detailed description.

FIGURE 1 diagrammatically shows a radiation therapy system including a radiation therapy planning module;

FIGURE 2 diagrammatically shows a radiation therapy planning method suitably performed by the radiation therapy planning module of the system of FIGURE 1; and,

FIGURES 3 and 4 diagrammatically show a region that diagrammatically illustrates selected operations of the method of FIGURE 2.

With reference to FIGURE 1, a radiation therapy system includes an imaging modality **10** suitable for acquiring planning images for planning radiation therapy. In some embodiments, the imaging modality **10** is a computed tomography (CT) scanner. For example, the CT scanner has a large patient aperture, 85 cm for example, which is large enough to accommodate the patient arranged in typical radiation therapy positions.

Other CT scanners can be used instead, as well as other imaging modalities such as positron emission tomography (PET), magnetic resonance (MR), single photon emission computed tomography (SPECT), and so forth. Acquired images are stored in an image memory **12**, which may be in a central electronic records storage system. The planning image is typically acquired of the subject scheduled to undergo the radiation therapy. For example, the subject may be an oncology patient, or a veterinary subject, or the like. The term "planning image" in this context relates to the images that are used to plan radiation therapy sessions. The planning images (or set of planning images), for example, generated at two different times, are used in generating deformation maps, which describe the deformations that transform or deform the planning image generated at one time into a common coordinate system and registered with the planning image taken at a different time.

Modeling anatomical shape change as deformation, such as by a deformation map, uses landmarks, features, surfaces, and the like in 3-D to define a mapping (transformation) between two images or sets of images (e.g., of the same anatomy) into the same coordinate frame or frame of reference. Various algorithms are available for performing these mappings or transformations among sets of images. Once landmark and/or features and/or surfaces are identified and paired between the images, these points are used to compute a coordinate transformation that maps every coordinate location in one image to a corresponding location in the other image and align them accordingly into one coordinate system, which is called image registration.

A planning module **20** receives planning images at various times during a radiation therapy process. The module **20** updates an earlier radiation therapy plan (RTP) and its cumulative dose map to compensate for anatomical changes, e.g., shrinking, expanding, shifting, etc, during prior therapy sessions. A first planning image is generated and a first RTP is generated. After one or a series of therapy sessions, a subsequent planning image is generated and the module **20** updates the RTP.

The planning module **20** includes automatic segmentation tools **22** and manual segmentation and editing tools **24**. Model based segmentation or other methods are used to modify a representation of the ROI boundaries, such as by contours, binary mask, or mesh vertices therein and/or the POI positions. The segmentation tools are used to delineate, e.g., with superimposed contours and/or dots, target Object(s) of Interest (OOIs) including Region(s) of Interest (ROIs) and/or Point(s) of Interest (POIs) and other adjoining ROIs, OOIs, and/or POIs particularly at risk regions in which radiation dose is to be limited. The manual segmentation tools include editing tools, which allow the user to manually adjust image features, particularly the segmentation contours and/or the landmark positions when the images are displayed on a display **26**. Manual inputs **28**, such as a keyboard or mouse, enable the user to use various virtual tools to push or pull the OOIs to change their shapes and positions to conform more accurately to the image content.

For example, the radiation target region may be a cancerous tumor, and the one or more risk regions may include neighboring vital organs or tissue whose radiation exposure should be kept below a maximum value. Toward this end, the radiation therapy planning is responsive to dose plan parameters that are indicative of dosage or dosage constraints for the radiation target region and the one or more risk regions. An accumulated dose map is generated which shows the cumulative radiation dose which the treatment plan delivers to each region.

The planning module **20** also includes a deformable or elastic registration module which can implement one or more deformable, elastic registration algorithms **30**. A variety of such algorithms are known in the art. The deformable registration algorithms compare two images of a common area of the same subject to determine the differences between them and generate a transform, such as a deformation map, which can be applied to one of the images to transform it into alignment or registration with the other. These algorithms typically register the image as a whole and can have local inaccuracies, particularly around a tumor that is shrinking.

One of the ways to determine the accuracy of the mapping is to analyze the propagated OOI locations. In one embodiment, if the user or the examining specialist decides that the propagated OOI locations were not mapped correctly, the editing tool module **24** is utilized to adjust contour points and/or features on the OOI locations propagated onto the second image. The specialist can adjust the OOI locations manually using contour or mesh editing, for example. The same or a different algorithm of the deformation image registration algorithm module **30** is then used to generate a new or corrected deformation map based on corresponding points of the locations of the original or first planning image set and the edited locations on the second image.

The planning module **20** also includes a radiation therapy planning module or algorithm **32** which can generate an initial RTP and update the RTP including the accumulated dose each time a subsequent planning image is generated. To update the accumulated dose from a first treatment session, the corrected deformation map is applied to the subsequent plan to conform the OOIs and their dose to the planning image for a second treatment session. In this manner, the accumulated radiation in each OOI is accurately determined over a plurality of treatment sessions even as OOIs shift, shrink, expand, change shape, or the like.

A deformable image registration can be used, for example, when a radiologist compares images acquired before and after administration of a contrast enhancing pharmaceutical that highlights malignant masses. If a tumor was shrunk by the therapy, the tumor is smaller and the surrounding OOIs have relaxed back closer to their normal location. Comparison of images before and after an intervention, such as radiation therapy, is performed. A simple change in position can cause apparent deformation of a breast, for example, which further complicates the comparison. Matching or image mapping is therefore performed to eliminate the deformation. The differences remaining between the original 3-D images and the non-ideally corrected images can be determined by subtracting the two images and taking an absolute value of the result.

A control processor **34** controls the modules and algorithms to perform the method described in conjunction with FIGURE 2.

The radiation therapy plan generated by the radiation therapy planning module **20** after adjustment of any propagated OOIs is stored in a radiation therapy plan memory **50**. At the scheduled day and time for the radiation therapy session, a radiation therapy apparatus **52** is employed to deliver therapeutic radiation to the subject controlled by a radiation therapy control system **54** in accordance with the radiation therapy plan stored in the memory **50**. For example, in the illustrated embodiment the radiation therapy delivery apparatus **52** is a tomotherapy linear accelerator (LINAC), and the radiation therapy control system **54** operates multi-leaf collimator (MLC) or other radiation beam profile-shaping apparatus of the LINAC **52** to modulate beam intensity and profile as the linear accelerator is moved around the subject, so as to deliver a radiation dose distribution into the subject that provides the desired integrated radiation dosage to the target feature while suitably limiting or constraining radiation exposure of sensitive critical features in accordance with the radiation therapy plan.

The radiation therapy planning module **20** can be embodied by a single digital processor, two or more digital processors, computers, application-specific integrated circuitry (ASIC), or so forth. Similarly, the radiation therapy planning including editing tools for generating deformation maps may be embodied by a storage medium storing instructions executable by a digital processor to perform the planning. For example, the storage medium may be a hard disk or other magnetic storage medium, an optical disk or other optical storage medium, a random access memory (RAM), read-only memory (ROM), FLASH memory, or other electronic storage medium, various combinations thereof, or so forth.

With reference to FIGURE 2, an illustrative radiation therapy planning method suitably performed by the system of FIGURE 1 is described. In an operation **60**, a first planning image is generated and/or displayed. The initial first planning image is segmented **62** to define initial segmentation contours of the target and other OOIs. The operation **62** can employ initial contouring utilizing automatic segmentation of the planning image, a semi-automatic segmentation, or manual segmentation of the OOIs. Once the initial or first planning image is segmented, a radiation therapy planning (RTP) operation is calculated **63**. In one embodiment, the radiation therapy plan is generated using commercially available software. In other embodiments, the RTP plan is generated semi-automatically or manually.

Any image segmentation operation **62** and RTP operation **63** can be performed using the radiation therapy planning module **20**. In an operation **77**, the initial radiation therapy plan is implemented to treat the patient. For example, the LINAC **52** is used to irradiate the patient over one or a series of therapy sessions.

After the first therapy session(s), a second planning image or image set is generated at an operation **64**. In a registration step **65**, the first and second sets of planning images, e.g. 1st and 2nd 3-D images, are registered using a deformation algorithm to determine a transform, usually a deformation map **66**, which brings the first and second planning image sets into registration or alignment. For example, a constant volume, 3-D, second order Taylor series propagation or warp to the original images can be performed. (see, Davis, Malcolm H., “A Physics-Based Coordinate Transformation for 3-D Image

Matching" in IEEE Transactions on Medical Imaging, Vol. 16, No. 3 (1997). Other types of deformable image registration algorithms are also envisioned by the presented disclosure as one of ordinary skill in the art will appreciate, such as demons, b-spline, level set and the like.

The deformation map can be generated by various transformations, such as spline algorithms, for example, a thin plate spline transform based on corresponding mesh vertices of the segmented contours or features. A set of images is used in order to perform image registration of the OOIs in a patient, for example. Image registration allows the comparison or integration of data points obtained from different measurements at various times. For example, multi-dimensional splines (e.g., a thin plate spline, or the like), a volume spline, elastic spline, or other imaging registration algorithms may be used in generating a deformed planning image.

The locations of the OOIs including ROI contours and/or POI positions of the first planning image set are propagated or warped **67** with the deformation map and overlaid on the second planning image set for display **68** with propagated OOIs. The difference between the propagated OOI locations and the actual OOI locations is determined and corrected in a local OOI correction operation **70**, including ROI contour corrections and/or POI position shifting, to bring the OOIs into coincidence with the image contents. The correction can be automatic, semi-automatic, or manual. In a manual OOI correction operation, the second planning image set is overlaid with the propagated OOI locations. The image content information and the user's knowledge are used to determine the accuracy of the propagated OOIs and modify these using editing tools if there is error. Interactive software tools, such as mesh editing, paint brush, or any method allowing the user to modify representations of ROIs, such as contours, binary making, or mesh vertices may be implemented. In an automatic OOI correction operation, the propagated OOIs would be automatically adjusted to the image content using an algorithm such as model based segmentation which may also incorporate shape priors or the like. Note that in an automatic OOI correction operation, previous display operation **68** may be skipped.

In an operation **72**, a corrected deformation map is generated from manual and/or automatic OOI correction operations. In the case of both manual and automatic correction operations, corresponding landmark (POI) positions are used as well as corresponding points selected at locations distributed along the ROI contours. Methods of

ROI contour point selection vary from random selection through regular sampling to algorithms that determine boundary surface areas with large curvature, points that represent ROI extents, for example. Various algorithms such as 3-D affine transformation, thin plate spline, volume spline, or elastic body spline, etc, may be used to generate a new deformation map based on either the selected corresponding OOI points entirely or a combination of the selected corresponding OOI points and the original deformation transform or corresponding points.

In an operation **72**, the various algorithms and the like discussed above are used to achieve a global update or correction of the deformation map to account for local manual and/or automated OOI corrections in a previous operation **70**. This may be performed iteratively **74** until all propagated OOI locations are corrected or until all planning criteria are met. During the deformation map correction process, the display **26** displays the second planning image set overlaid with the OOI locations propagated from the first planning image.

Once the deformation map is satisfactorily corrected, e.g. within preselected accuracy criteria, the deformation map is applied by the radiation therapy plan and the accumulated dose map to generate an updated radiation dose map in an operation **76**. Applying the deformation map to the accumulated dose map transforms the OOIs and their accumulated doses into conformity with the OOIs of the planning map for calculating the RTP for the next therapy session. Once the updated dose map is approved by the radiologist, the patient undergoes one or a series of therapy sessions **77**. After the therapy session(s), in preparation for a next one or series of sessions, a third planning image set is generated and the above-described steps are repeated. Additional planning images, updated deformation maps, updated radiation therapy plans and updated accumulated dose maps are generated as needed over the course of the therapy.

Although described in terms of registering the first planning image or set to the second planning image set, the second planning image or set could be registered to the first planning image set.

FIGURES 3 and 4 illustrate an example of the OOI correction operation **70** and the basis for deformation map correction operation **72**. An initial planning image is segmented to define an ROI contour **90** of a tumor, an organ at risk, or one or more other contoured ROIs or positioned landmark POIs or any OOIs, for example. Although ROIs or

POIs may be referred to herein, the disclosure is not limited to either one, and includes both in addition to OOIs of an image accordingly. The first planning image is captured by a CT, MR, or other imaging modality **10**. Operating on the first image with the initial deformation map in operation **67** propagates the ROI contour **90** to a propagated ROI contour **92** and the POI position **91** to a propagated POI position **93**. In display operation **68**, the propagated ROI contour **92** and the propagated POI position **93** are overlaid on the image contents of a new or second planning image, in which appears the desired shape **94** of the ROI, and the desired position **95** of the POI. Points of correspondence **96** between the initial OOIs and the propagated OOIs, namely selected corresponding points on ROI contours and corresponding POI positions, highlight the inaccuracy of the deformation map with respect to image contents. In FIGURE 4, manual and/or automated OOI correction methods in operation **70** have produced the corrected ROI contour **92'** and the corrected POI position **93'** so as to bring these OOIs in coincidence with the desired locations **94** and **95** in the second planning image. These local OOI corrections provide corrected points of correspondence **96'** between the OOIs in the first planning image and the corrected OOI locations in the second planning image, which are used to correct the global deformation map. Once the deformation map has been fully corrected, applying the corrected deformation map to the first planning image would propagate the points of correspondence **96'** of the re-propagated OOI locations **92'** and **93'** into better coincidence with the second planning image contents **94** and **95** (the correspondence **96'** would be exactly satisfied in the case where the deformation map method relies on interpolation, whereas it would be better approximately satisfied in the case where the deformation map method relies on approximation).

In one embodiment, the OOI corrections are carried out directly with the editing tools of editing sub-module **24** without any further calculation or algorithm being implemented before generating the corrected deformation map. In another embodiment, a region **R** in FIGURE 3 illustrates the difference between points of correspondence at the first propagated contour **92** and the structure ROI **94** in the second image. Radiation dose in region **R** could erroneously be attributed to the ROI defined by contour **94** rather than the adjacent ROI in the second planning image. Computer implemented algorithms can be used to reduce the difference to zero.

Afterwards, the newly corrected deformation map is able to be applied to volumes, such as in a moving image, a dose volume, or any other desired volume and/or any other OOIs.

With a visualization as illustrated in FIGURES 3 and 4, a radiologist or other medical professional performing the contouring benefits by receiving visual "importance" feedback during the manual contouring, or by integrating an importance feature along the contours into an automated segmentation algorithm in the case of automated or semi-automated contouring. In some embodiments, the corrected points of correspondence are input to an automated segmentation/contouring algorithm, which allows for relaxation of the accuracy requirements of the automated algorithm. In manual contouring, the technician is informed of which areas of the initial contour delineation need to be improved.

Looking to a specific application, such as prostate treatment planning, the radiation target region is the prostate and the risk regions to be delineated typically include femur heads, the bladder, and the rectum. Certain contour segments are unlikely to have high impact regardless of the accuracy of delineation, while other contour segments need to be very accurate. In interactive segmentation, a learned or pre-calculated impact values become part of (i.e., *a priori* knowledge included in) a model used for automated or model-based segmentation. During the model-based segmentation process the impact values are used as an additional (probabilistic) feature to balance accuracy in areas where contours are difficult to delineate. In such embodiments the calculation of dose during the segmentation can optionally be avoided.

The disclosure has been described with reference to various embodiments. Modifications and alterations may occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

CLAIMS:

1. An apparatus comprising:

a planning module (20) for updating a first radiation therapy plan (RTP) generated with a first planning image set that has been segmented to define locations of Object(s) of Interest (OOIs), including contours delineating Region(s) of Interest (ROIs) and/or landmarks indicating Point(s) of Interest (POIs) in the first planning image set, the planning module being configured to:

receive a second planning image set from an imaging device (10);

register the first and second planning image sets to generate a first deformation map which transforms one of the planning image sets into alignment with the other;

operate on the OOI locations with the deformation map to propagate the OOI locations onto the second planning image set;

allow manual and/or automatic corrections of propagated OOI locations (70) in accordance with deviations between the propagated OOI locations and the second planning image set or locations of the corresponding OOIs in the second planning image set;

generate a corrected global deformation map (72) in accordance with local OOI location corrections; and

adjust the RTP with the corrected deformation map to generate an updated RTP.

2. The apparatus according to claim 1, wherein the planning module (20) is further configured to:

receive a first cumulative dose map indicative of cumulative dose received by each of the OOIs during one or more treatment sessions performed in accordance with the first RTP;

operate on the first cumulative dose map with the corrected deformation map to generate a second cumulative dose map.

3. The apparatus according to either one of claims 1 and 2, further including:

a display device (26) on which the propagated OOI locations overlaid on the second plane image set are displayed; and

a user input device (28) by which a user controls editing tools of the planning module to adjust the propagated OOI locations.

4. The apparatus according to any one of claims 1-3, further including:

one or more diagnostic image devices (10) which generate the first and second planning image sets;

a radiation therapy control system (54) which controls a radiation therapy device (52) to implement the updated RTP.

5. The apparatus according to any one of claims 1-4, wherein the planning module is further configured to:

segment the first planning image set; and

generate the first RTP from the segmented first planning image set.

6. A method of updating a first radiation therapy plan (RTP) generated from a first planning image set that has been segmented to define locations of Object(s) of Interest (OOIs), including contours delineating Region(s) of Interest (ROIs) and/or landmarks indicating Point(s) of Interest (POIs) in the first planning image set, the method comprising:

receiving a second planning image set (64);

registering the first and second planning image sets with a computer-implemented algorithm to generate (65) a first deformation map (66) which transforms one of the planning image sets into alignment with the other;

operating on the OOI locations with the deformation map to propagate the OOI locations onto the second planning image set (67);

allowing manual and/or automatic corrections of propagated OOI locations (70) in accordance with deviations between the propagated OOI locations and the second planning image set or locations of the corresponding OOIs in the second planning image set;

generating a corrected global deformation map (72) in accordance with local OOI location corrections; and

adjusting RTP with the corrected deformation map to generate an updated RTP (76).

7. The method according to any one of claims 1-6, wherein the initial RTP includes a cumulative dose map and further including:

operating on the original dose map with the corrected deformation map to generate an updated dose map.

8. The method according to either one of claims 6 and 7, further including:

controlling a radiation therapy device to implement the initial RTP prior to generating the second planning image set;

controlling the radiation therapy device to implement the updated RTP after generating the second plan image set.

9. The method according to any one of claims 6-8, wherein the registration algorithm (30) includes an elastic transformation, such as a thin plate or surface spline algorithm.

10. The method according to any one of claims 6-9, further including:

displaying the propagated OOI locations overlaid on the second planning image set on a display device (26).

11. The method according to any one of claims 6-10, wherein correcting the deformation map includes:

identifying corresponding points on the propagated ROI contours and the second planning image; and

determining deviations between the corresponding points.

12. The method according to claim 10, wherein the deviation between points of correspondence are determined by manually adjusting (100) the propagated OOI locations.

13. The method according to claim 12, wherein the adjusting includes: using editing tools to manipulate the propagated OOI locations.

14. The method according to claim 13, wherein the editing tools include at least one of a contour, mesh vertex, or binary mask editing tool to manually editing.

15. The method according to claim 11, wherein the deviation between points of correspondence is determined by automatically adjusting the propagated OOI locations using a computer implemented algorithm to bring the propagated OOI locations into coincidence with the second planning image set or corresponding OOI locations of the second planning image set.

16. The method according to any one of claims 6-15, further including:
generating the first and second planning image sets;
segmenting the first planning image set;
generating the first radiation therapy plan from the segmented first planning image set.

17. A digital processor (54) configured to perform the method according to any one of claims 6-16.

18. A non-transitory computer-readable medium carrying instructions executable by one or more digital processors to implement the method according toany one of claims 6-16.

19. A radiation therapy planning system comprising:

diagnostic imaging device (10);

radiation therapy device (52);

display device (26);

one or more processors (20) programmed to perform the method according to any one of claims 6-16.

20. A radiation planning module configured to:

receive a first planning image that has been segmented to define locations of Object(s) of Interest (OOIs), including contours delineating Region(s) of Interest (ROIs) and/or landmarks indicating Point(s) of Interest (POIs);

receive a second planning image and a third planning image that are in a common coordinate frame;

register the first planning image with the second or third planning image and generating a first deformation map which transforms the first planning image into alignment with the second or third planning image;

operate on the defined OOI locations with the deformation map to propagate the OOI locations onto the second planning image;

allow manual and/or automatic corrections of propagated OOI locations (70) in accordance with deviations between the propagated OOIs and the second planning image set or locations of the corresponding OOIs in the second planning image;

generate a corrected global deformation map (72) in accordance with local OOI location corrections in the second planning image set; and

operate on the second planning image and the third image with the corrected deformation map such that the first planning image, the second planning image, and the third image are brought into the same coordinate frame.

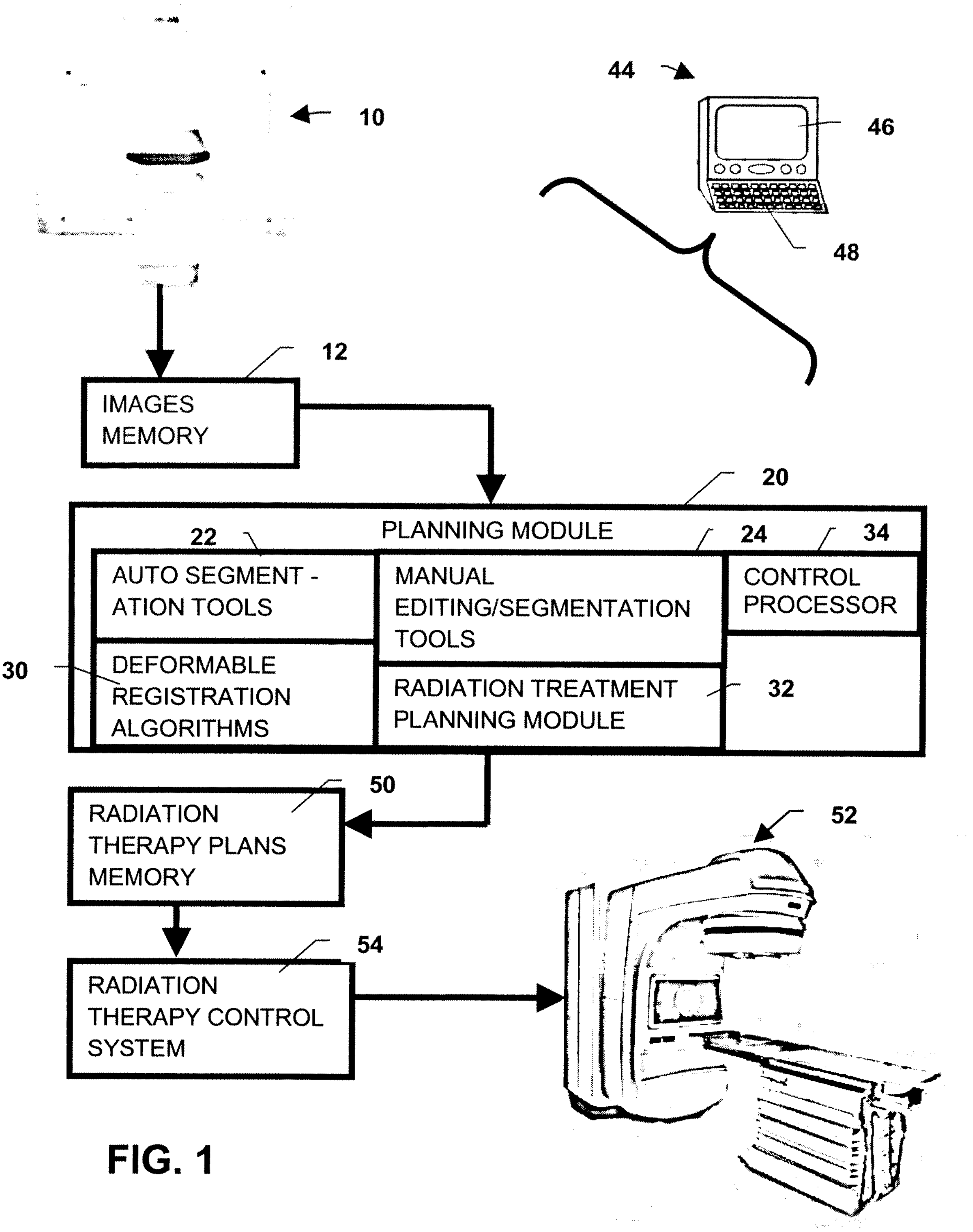
10
44
46
48
12
IMAGES MEMORY
20
PLANNING MODULE
22
24
34
AUTO SEGMENT - ATION TOOLS
MANUAL EDITING/SEGMENTATION TOOLS
CONTROL PROCESSOR
30
DEFORMABLE REGISTRATION ALGORITHMS
RADIATION TREATMENT PLANNING MODULE
32
50
RADIATION THERAPY PLANS MEMORY
52
54
RADIATION THERAPY CONTROL SYSTEM

FIG. 1

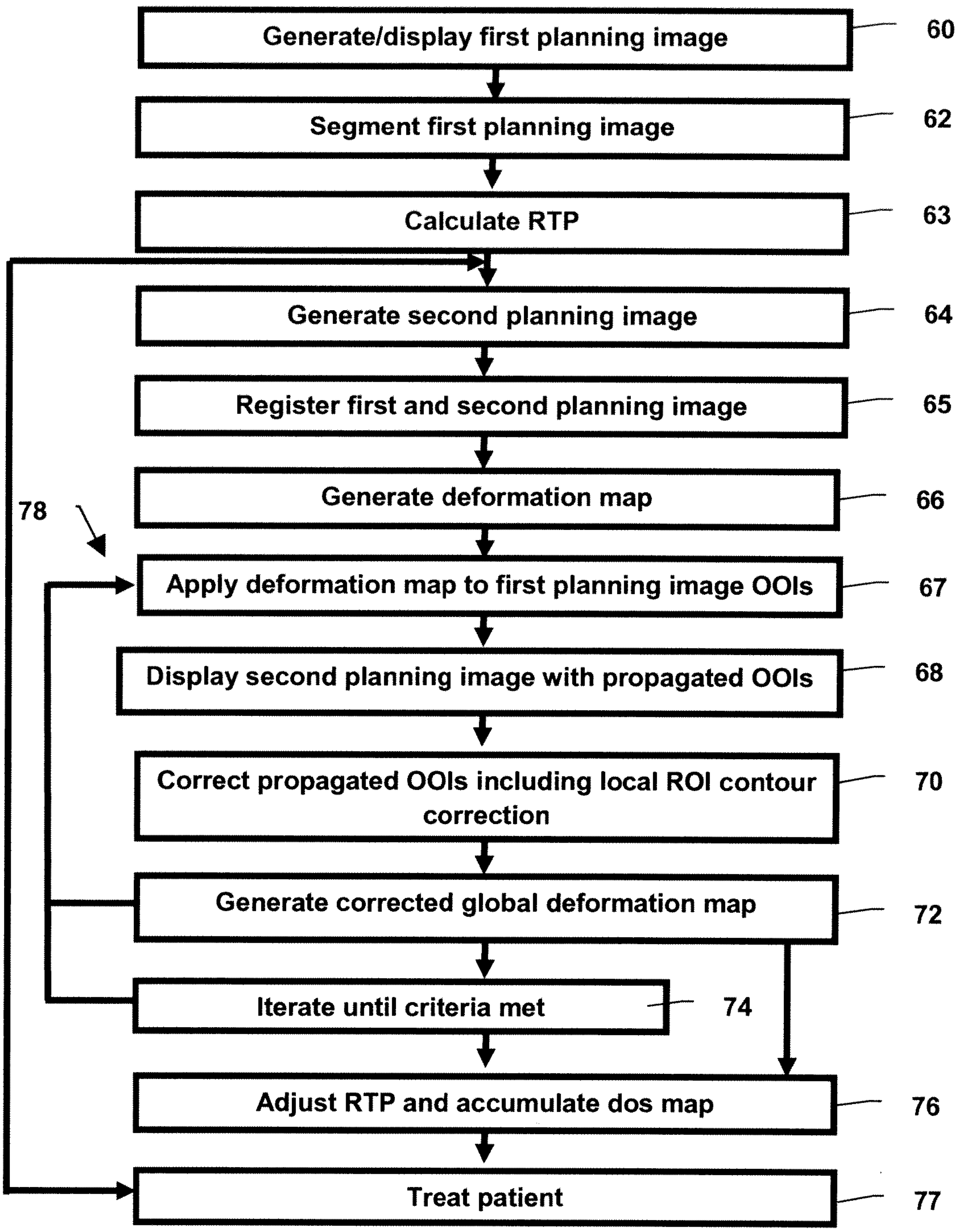
Generate/display first planning image
60
Segment first planning image
62
Calculate RTP
63
Generate second planning image
64
Register first and second planning image
65
Generate deformation map
66
78
Apply deformation map to first planning image OOIs
67
Display second planning image with propagated OOIs
68
Correct propagated OOIs including local ROI contour correction
70
Generate corrected global deformation map
72
Iterate until criteria met
74
Adjust RTP and accumulate dos map
76
Treat patient
77

FIG. 2

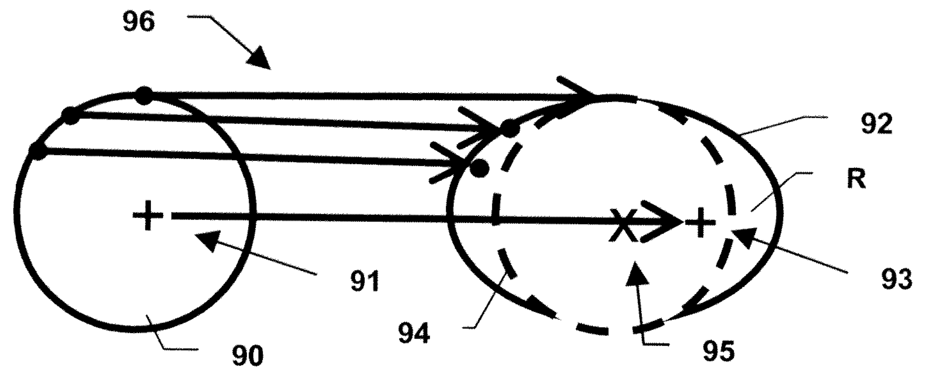

FIG. 3

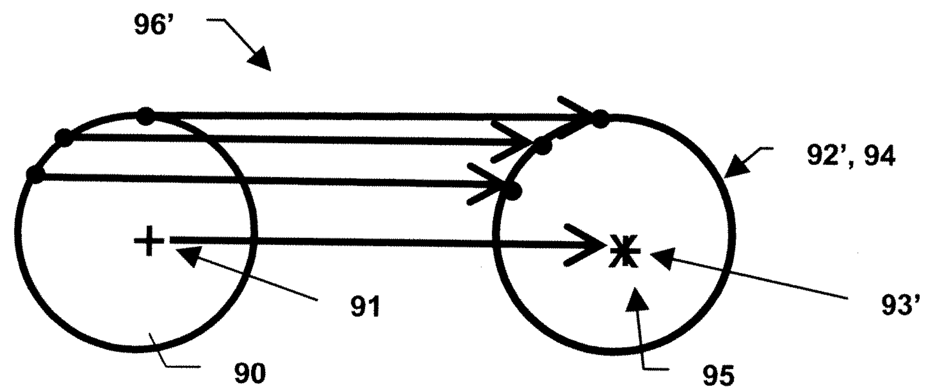

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2011/055145

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61N5/10
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007/014092 A2 (TOMOTHERAPY INC [US]; LU WEIGUO [US]; OLIVERA GUSTAVO H [US]; RUCHALA) 1 February 2007 (2007-02-01) the whole document -----	1-5, 17-20
X	WO 2007/014105 A2 (TOMOTHERAPY INC [US]; LU WEIGUO [US]; RUCHALA KENNETH J [US]; OLIVERA) 1 February 2007 (2007-02-01) abstract paragraph [0025] - paragraph [0053] paragraph [0069] - paragraph [0071] -----	1-5, 17-20
A	US 2005/251029 A1 (KHAMENE ALI [US] ET AL) 10 November 2005 (2005-11-10) abstract paragraph [0011] - paragraph [0018] -----	1-5, 17-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 March 2012	10/04/2012

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Authorized officer
Beck, Ewa

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2011/055145

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 6-16
because they relate to subject matter not required to be searched by this Authority, namely:

Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2011/055145

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		EP 1907058 A2	09-04-2008
		JP 2009507524 A	26-02-2009
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